

ADVANCED FLUID MECHANICS
(MECH 3233)

Time Allotted : 2½ hrs

Full Marks : 60

Figures out of the right margin indicate full marks.

*Candidates are required to answer Group A and
any 4 (four) from Group B to E, taking one from each group.*

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve:

12 × 1 = 12

Choose the correct alternative for the following

- (i) The flow of liquid through the hole in the bottom of the washbasin is an example of
 - (a) forced vortex flow
 - (b) free vortex flow
 - (c) uniform flow
 - (d) steady flow.
- (ii) In case of forced vortex flow, the height of the parabolic free surface, varies with
 - (a) fourth power of radius
 - (b) cubic power of radius
 - (c) square of radius
 - (d) directly proportional to radius.
- (iii) The boundary layer exists due to
 - (a) gravitational force
 - (b) surface tension
 - (c) density of fluid
 - (d) viscosity of fluid.
- (iv) When velocity potential exists in a flow it means
 - (a) flow satisfies the condition of rotational flow
 - (b) vorticity is non zero
 - (c) flow satisfies the condition of irrotational flow
 - (d) all of the above.
- (v) In a laminar flow between two stationary parallel plates, the ratio of maximum velocity to average velocity is equal to
 - (a) 1
 - (b) 1.5
 - (c) 2
 - (d) 2.5.
- (vi) If we reverse the direction of velocities of a sink flow, it becomes
 - (a) counter sink flow
 - (b) source flow
 - (c) a free vortex
 - (d) a forced vortex.
- (vii) The Von Karman momentum integral equation is applicable to
 - (a) laminar, transitional and turbulent boundary layer flows.
 - (b) only laminar boundary layer flow
 - (c) only turbulent boundary layer flow
 - (d) none of these.

- (viii) Fluid is flowing through a duct with a Mach number equal to 0.7. An increase in cross-section area in the downstream will cause an
 (a) decrease in velocity (b) increase in velocity
 (c) increase in static pressure (d) choked flow situation.
- (ix) For a sphere falling under its own weight through a viscous fluid with very low Reynolds number of flow ($Re \ll 1$), the drag coefficient (C_D) and Reynolds No (Re) is related by
 (a) $C_D \times Re = 1$ (b) $C_D \times Re = 1/24$
 (c) $Re = 24 / C_D$ (d) $C_D = Re / 24$
- (x) When compared to a streamlined body, a bluff body will have
 (a) more pressure drag but less friction drag
 (b) more pressure drag and more friction drag
 (c) less pressure drag and less friction drag
 (d) less pressure drag but more friction drag.

Fill in the blanks with the correct word

- (xi) The maximum velocity of a one-dimensional incompressible fully developed viscous flow between two fixed parallel plates, is 6 m/s. The mean velocity of the flow is _____ m/s.
- (xii) For a supersonic flow, if the Mach angle is 30° , the value of Mach number is _____.
- (xiii) The steady irrotational flow of an incompressible fluid is called _____.
- (xiv) When a body is immersed in a flow field, the component of the resultant force acting on it in the direction normal to the relative velocity is called _____ force.
- (xv) The velocity components in the x-and y directions of two-dimensional potential flow are u and v, respectively, then $\frac{\partial u}{\partial x}$ is equal to _____.

Group - B

2. (a) If the velocity field is given by $u = 4y - 2x$ and $v = 2y - x$, then determine the circulation and vorticity around the closed curve defined by $x = 2, y = 1, x = 4$ and $y = 4$. [[CO1](Analyse/IOCQ)]
- (b) In a two-dimensional flow, the stream function is given by $\psi = 2xy$. Show that the flow is irrotational and it also determines the corresponding velocity potential. [[CO1](Analyse/IOCQ)]
- 6 + 6 = 12**
3. (a) Prove that in case of forced vortex, the rise of liquid level at the ends is equal to the fall of liquid level at the axis of rotation when there is no spillage. [[CO1](Understand/LOCQ)]
- (b) An open cylindrical tank of diameter 0.5 m and height 0.9 m is completely filled with water. It spins about its vertical axis at 104 rpm. Determine the water left in the tank when it reaches to its full speed. [[CO1](Apply/IOCQ)]
- 6 + 6 = 12**

Group - C

4. (a) Show that in case of Couette flow, the shear stress at the horizontal mid-plane of the channel is independent of the pressure gradient imposed on the law. [[CO2](Understand/LOCQ)]
- (b) Two parallel plates are fixed apart with a gap of 2.5 mm. A crude oil flows through the gap between these two plates due to drop in pressure from A to B of 5 kPa. If the plates are 1000 mm wide, determine the flow (discharge). [[CO2](Analyze/IOCQ)]
6 + 6 = 12
5. (a) Velocity profile of laminar boundary layer is given by $\frac{u}{U_\infty} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$. Determine the expressions for boundary layer thickness (δ) and shear stress (τ_0) in terms of Reynolds number. [[CO4](Analyze/IOCQ)]
- (b) Two horizontal plates 10 mm apart contain oil of viscosity 0.86 poise. If the upper plate is moving with 1.2 m/s with respect to the lower plate which is stationary and the pressure difference between two sections 80 m apart is 80 kPa, then calculate the velocity distribution, shear stress on the upper plate and discharge per unit width. [[CO2](Analyze/IOCQ)]
6 + 6 = 12

Group - D

6. (a) Find the speed of propagation of a small disturbance through a compressible fluid in terms of change in pressure and change in density. [[CO3](Remember/LOCQ)]
- (b) A supersonic plane in its flight has a Mach angle of 40° and is flying in air, having a temperature -30°C . Calculate the speed of the plane. (For air, $\gamma = 1.4$ and $R = 287 \text{ J/kg-K}$) [[CO3](Evaluate/HOCQ)]
6 + 6 = 12
7. (a) A nozzle is designed to expand air isentropically to atmosphere pressure from a large tank in which properties are held constant at temperature 5°C and pressure 304 kPa (abs). The desired flow rate is 1 kg/s. Determine the exit area of the nozzle. [[CO3](Apply/IOCQ)]
- (b) A tank containing air at a pressure of 250 kPa (abs) and temperature 35°C , is discharging it through a convergent nozzle. If the velocity of flow at the nozzle exit is 200 m/s, find whether the flow is subsonic, sonic or supersonic, at that section. (For air, $\gamma = 1.4$ and $R = 287 \text{ J/kg-K}$). [[CO3](Apply/IOCQ)]
6 + 6 = 12

Group - E

8. (a) A man, descends to the ground from an aeroplane with the help of a parachute against the resistance of air with an uniform velocity of 25 m/s. The total mass of the man and the parachute is 80 kg. The shape of the parachute is

hemispherical. Find the diameter of the parachute. Assume $C_d = 0.5$ and $\rho_{\text{air}} = 1.25 \text{ kg/m}^3$. [[C05](Apply/IOCQ)]

- (b) The flow over a plane half body is studied by superimposing a uniform flow at 5 m/s in a source at the origin. If the stagnation point occurs at $(-0.5, 0)$, then determine (i) the strength of the source, (ii) maximum width of the Rankine body and (iii) width of the Rankine body at the source. [[C06](Analyze/IOCQ)]

6 + 6 = 12

9. (a) What is meant by a Doublet? Define the strength of a Doublet. How is it possible to obtain the flow pattern of a Doublet? [[C06](Remember/LOCQ)]
- (b) If a circular cylinder of diameter 0.5 m rotates at 600 rpm in a uniform stream of 15 m/s, then locate the stagnation point and determine the minimum rotational speed for detached stagnation points. [[C06](Analyze/IOCQ)]

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	25	68.75	6.25

Course Outcome (CO):

After the completion of the course students will be able to

- CO 1** • Understand the fundamental principles for solving kinematics of fluid flow.
- CO 2** • Analyze standard bench mark problems like Couette flow, Poiseuille flow.
- CO 3** • Apply the fundamental laws to solve problems of compressible fluid flow in engineering systems.
- CO 4** • Relate different flow parameters for boundary layer flow over flat plate.
- CO 5** • Evaluate the effects of drag and lift force on submerged bodies
- CO 6** • Explain various phenomena for ideal fluid flow

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.